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LABORATORY INVESTIGATIONS OF BIOMEDICAL FACTORS
INFLUENCING LASER DESIGNATOR OPERATOR PERFORMANCE.

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INTRODUCTION

Laser rangefinder-designators have been developed for use in various military operational environments. In a typical engagement, the rangefinder-designator is located at a known position overlooking the target coordinates. A laser-seeking missile or artillery round is fired at these coordinates. During the last several seconds of projectile flight time, the laser beam is directed to the target and the projectile is guided toward the reflected laser radiation.

In a tactical scenario, an enemy tank which is capable of sensing the laser irradiation, will turn and fire at the laser designator operator. Blast effects (flash/noise, over-pressure, dust, debris) and/or the psychological threat of the tank's response could disrupt the designator operator's performance to the extent that the missile or artillery projectile may miss its designated target. The U.S. Army is presently planning to train laser designator operators. Additional information is needed regarding environmental effects on operator performance and individual differences in performance capacities.

A field simulation laboratory has been constructed which will facilitate the controlled investigation of factors which may influence laser designator operations. The primary objectives in developing this laboratory were to obtain accurate low-cost on-line assessment of pursuit tracking performance under conditions where experimental variables could be precisely controlled. An attempt

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was made to reproduce, in the laboratory, some of the conditions encountered in a field situation. The scenario which has been implemented consists of a sandbag bunker, desert terrain model, a viscous-mounted laser designator, scale-model targets, and a central control room.

Data have been collected in this simulator for comparison with normative data obtained under field conditions. During these studies, the effects of training, target angular velocity, and ambient lighting conditions were investigated. The results of these studies will be presented. ✓

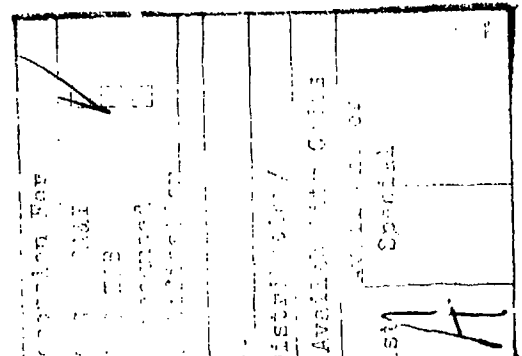
METHODS

Bunker. The sandbag bunker, which is consistent in design and construction to standard bunkers (1), is used to control the soldiers' working environment and to provide a degree of isolation from distractions occurring elsewhere in the laboratory. Light levels within the bunker are continuously adjustable by means of a solid-state controller located outside the bunker. The viewing port of the bunker opens into a large cone which restricts the view so that only the terrain model is visible from inside the bunker. The occupant's view of the terrain is further restricted to what one can see through the optics of the designator device.

The inside of the bunker is equipped with near infrared light sources and an infrared television (TV) to monitor the inside of the bunker under all lighting conditions. The bunker also contains overhead speakers which can be used to provide sound effects (e.g., blast effects of incoming projectiles). Two-way communication with the control room is provided. An instrumentation interface is provided to enable complete physiological monitoring of the occupant(s) of the bunker.

Terrain Model. The present terrain model (Fig 1) represents a desert environment but may be modified to simulate other operational environments. The terrain model is 6 m wide and 4.8 m deep. The near portion of the terrain begins 1.5 m in front of the outside wall of the bunker. The platform supporting the terrain model has been elevated to a position slightly below the level of the bunker view port. An observer inside the bunker is, therefore, provided with a low-angle view of the terrain.

A dry river bed and several small hills are included as part of the natural features. The use of scaled landscape features was



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avoided during terrain construction. Thus, targets of various scales may be employed without extensive modification of the terrain.



Figure 1. Scale model tank and simulated desert terrain.

Laser Designator. The optical tracking device was designed to reproduce the characteristics of a laser designator but does not include an active laser device. A unity power scanning scope is mounted in a fabricated metal box, which is affixed to a 500,000 centistoke viscous-damped traversing unit (Model 50 fluid head, O'Connor Engineering Laboratories). The damping characteristics of the mount can be adjusted to equal those of traversing units which are currently being considered for field deployment. Two rear-mounted handles (approximately shoulder-width apart) are used to aim the designator. The relatively close proximity of the target to the designator also requires that the mechanical response of the device be adjusted so that the effects of angular displacement

during tracking are matched to the simulated distances. A unique optical and mechanical compensating system was developed for this purpose. A 13-to-1 amplification of vertical and horizontal motion is obtained through use of levers which are linked to a moveable mirror located in the optical axis of the scanning scope. The line-of-sight rotates 13 times as fast as the mechanical rotation of the designator axis to simulate a 13-power optical system. This will provide the correct relationship between operator movement and displacement of the scope crosshairs on the target for any simulated engagement distance. The tracking device also contains an integral television camera. The camera line-of-sight is made colinear with the operator's line-of-sight by a dichroic mirror which reflects the far red spectrum to the camera and denies it from the operator's view. The output of the camera is used to provide a remote monitoring of the operator's field of view during tracking. These data are digitally processed to obtain tracking performance data. A strobe unit mounted in the optical train permits flash-effects studies to be performed.

Targets. The targets are scale-model tanks, available in 1/16 (Fig 1), 1/25, and 1/35 scale. Through appropriate selection of target scale and power of the designator simulator viewing optics, it has been possible to simulate various engagement ranges. The simulated range to the target is given by the expression:

$$R = \frac{Mr}{mS}$$

where,

R = range to be simulated in meters
M = power of the viewing optics of the designator
to be simulated, i.e., 13 for this system
r = range to tank model in meters
m = power of the designator simulator optics
S = scale of the tank model

If one assumes that unity power optics are used in the simulator and that the target is located 5 m from the designator, then the simulated engagement distances are 1.040 km (1/16 scale), 1.625 km (1/25 scale), and 2.275 km (1/35 scale).

Control and Data Acquisition. A central control room contains the TV monitors, data acquisition and recording instruments, and computer equipment. The TV monitors are used for observing the laser designator operator, to observe the target and terrain model, and to



monitor the view obtained through the designator optics. A Heath H8 microcomputer is used to manipulate experimental conditions, to control target movement, and to provide acquisition and analysis of performance data. The H8 is equipped with a dual-drive floppy disk system, and a specially designed interface board which processes tracking performance data. Summaries of operator performance data are provided on-line by the computer and permanent records are stored on floppy disks. Statistical summaries are written to a lineprinter at the end of each tracking trial. Automation of the simulation increases system flexibility and efficiency and allows the collection and processing of large amounts of data at relatively low cost. As a result, many experiments can be conducted in a relatively short period of time.

Horizontal and vertical error amplitude data are derived from the video output of the TV camera housed within the designator. Processing of the video signal to obtain error data is simplified by providing a red light emitting diode (LED) as a point source of light on the target. This source is readily detected by the TV camera while entirely invisible to the designator operator. When the ratio of target spot to ambient illumination is sufficiently high, it is relatively easy to adjust the monitor sensitivity controls to obtain a single point corresponding to the target spot. Error amplitudes are measured as a deviation of the target spot from a point on the monitor display corresponding to the optical axis of the designator camera.

Inexpensive methods have been developed for automatically detecting high contrast targets which are present in video signal channels (2,3). In the simulator, this is accomplished by using the following procedures. First, a vertical position counter circuit is reset to zero whenever the camera vertical synchronization pulse is detected. This event corresponds to the initiation of the first of a new series of horizontal scans by the camera. Each line occupies a unique vertical position within the series of horizontal lines which make up the picture. A separate horizontal position counter is triggered whenever a horizontal synchronization pulse is encountered. This event coincides with the beginning of each left-to-right scan of the camera. Within a horizontal scan, each element of the picture is associated with a unique time delay. A threshold circuit is adjusted to switch on whenever the relatively bright target spot is detected by the camera electronics. At the same time, the cumulative vertical (line number) and horizontal (elapsed time) counts are saved for further processing. With this method, error amplitude values may be obtained at a rate of up to 60 observations per second. The resulting time series of error

observations may be subjected to statistical analysis in the time or frequency domain. The stored horizontal and vertical counts are algebraically compared with the predetermined values corresponding to the optical axis of the designator in order to obtain separate horizontal and vertical error scores. The series of aiming error observations obtained during tracking trial are processed on-line to obtain estimates of the mean errors, root mean square (RMS) errors, the temporal location and magnitudes of maximum errors, and a percent time-on-target (TOT) score. The relatively simple TOT scores are derived by comparing the values of the pairs of vertical and horizontal observations against boundary values stored by the computer. The sensitivity of the TOT scores to tracking error can be changed by reprogramming the boundary conditions. The quantitatively superior (4,5) RMS error scores are emphasized as the primary criteria of tracking proficiency. The relatively less sensitive TOT scores are mainly used to provide trial-by-trial feedback to the operator. Within 30 sec of the end of each trial, a complete summary of performance data is presented on the control room operator's video terminal. Summary data are also written to a lineprinter. The complete records of digitized horizontal and vertical aiming errors are also recorded on floppy disk.

Validation Study

Subjects. The participants were 12 U. S. Army volunteers, 11 enlisted men and 1 officer. All volunteers received an extensive eye examination and visual function evaluation to determine acceptability. All individuals were emmetropic. The ages of the participants ranged from 22 to 38 years. None of the volunteers had received previous training in use of a viscous-mounted laser-designator type tracking device.

Simulator. In the present experiment, the body of an Athearn H0 model train engine was removed from the engine and frame and replaced with a Leopard A4 1/35 plastic scale model tank chassis. This target was mounted on a train track positioned in an arc 5.3 meters from the laser designator mount. Power to the track was provided by three model train transformers through a multiposition switch that allowed for rapid change among the three velocities that were used. The velocities were 2.5, 5.0, and 7.5 mrad/sec (at the simulated 2275 m engagement distance these velocities were approximately equal to 11.2, 22.4, and 33.6 mph). The model was equipped with a clearly visible aiming point, which consisted of a round black bullseye located at the center of a square white field. The target patch, as viewed through the designator optics, subtended a visual angle of

5.3 mrad. The corresponding traversing angle (the angular displacement of the designator when sweeping across the target) was 0.407 mrad.

The average terrain luminance, measured from the position of the designator objective lens, was $170 \text{ lm/m}^2\text{sr}$. The luminance reaching the eye was attenuated by the designator optics, which had a luminous transmittance of 10%. Low terrain luminance conditions were simulated by inserting a 2.5 OD neutral density attenuator in the designator optics but not in the TV camera line-of-sight. The apparent terrain luminance was thereby reduced to $0.54 \text{ lm/m}^2\text{sr}$. No light from the terrain passed into the bunker other than through the designator optics. The bunker light was turned off during the low-light tracking trials.

Procedure. When each soldier was asked to participate in the experiment, the nature of the research and all of the procedures were carefully explained and a volunteer consent statement was signed. An eye examination was given which included the Armed Forces Visual Acuity Test, Farnsworth Munsell 100-hue Color Vision Test, a dark adaptation test, undilated funduscopy examination, and a visual history. The color vision, acuity, and funduscopy examination were repeated after the experimental phase of the project. No test of oculomotor function was performed.

Each volunteer was given 30 training trials/day under the bright-light condition for 3 days (sessions 1, 2, and 3). During these sessions, 15 of the trials were run at 5.0 mrad/sec and 15 at 7.5 mrad/sec velocity.

Following the 90 training trials, 90 experimental trials were run (30 trials/day) that included 10 trials at each of three velocities (2.5, 5.0, and 7.5 mrad/sec). Each group of 10 trials were again divided such that 5 trials were performed under the bright-light condition and 5 under the low-light condition. The 15 trials under each light condition were combined, but the two light conditions were separated by a 10-minute rest period between trials 15 and 16. Five of the participants received the dark trials first and 7 received their light trials first. During the next two sessions, the order of the light/low-light conditions for each group was reversed from the previous day. The experimental sessions (i.e., 4, 5, and 6) were completed during the same 5-day work-week.

At the beginning of a session, the participant was seated in the bunker on sandbags which were adjusted for individual heights. If the first 15 trials were dark trials, the bunker light was turned off for 10 minutes to allow for partial dark adaptation to the

semi-darkened room. Following this, or if no dark adaptation was required (i.e., during the bright-light trials), at the command "ready" they would center the crosshairs of the designator on the target. At the command "go" the tank would begin an immediate right-to-left or left-to-right movement across the terrain. The total time of the track ranged from 10 to 12 seconds. Each trial was followed by a minimum delay of one minute, during which time the performance data were processed and summarized. Following this, the next trial would begin in the opposite direction.

Statistical Analyses. Separate analyses of variance (ANOVA) were computed for the analysis of the learning curve of the performance scores, including both RMS error and TOT scores, across all six sessions. For the evaluation of speed and light effects, horizontal RMS error and TOT scores for sessions 4, 5, and 6 (i.e., the experimental sessions) were also analyzed with separate ANOVA. The ANOVA were performed using Biomedical Computer Programs BMD-P2V for multifactorial mixed designs (6). The specific post hoc comparisons of significant findings were made using Newman-Keuls Tests (7). The 0.05 level was used for determining significances.

RESULTS AND DISCUSSION

Detailed summaries of the results of an evaluation of the microcomputer-controlled tracking error system, and the results of the tracking performance validation study, have been presented elsewhere (3,8). A brief summary of the results of the analyses of the horizontal RMS error data will be presented.

The effects of training on performance (Fig 2) across the three training sessions (1, 2, and 3) and the three experimental sessions (4, 5, and 6) are illustrated in Figure 2. These data were obtained during the bright-light condition only. The scores were the within session means (\bar{X}) of the 5.0 mrad/sec and the 7.5 mrad/sec velocity trials. The results of the ANOVA of the RMS error scores for the 5.0 and 7.5 mrad velocities indicated that there were significant repeated measure effects for both velocities. The post hoc comparisons showed, in general, a statistically significant improvement in performance when sessions 1 and 2 were compared with 3, 4, 5, and 6. However, with both velocities, despite the slight observable trend for continued improvement, no statistically significant differences were found when comparing the sessions subsequent to session 3. The means and standard errors of the means (SEM) of the X-axis and Y-axis RMS error data obtained during the last day of training were then compared to normative data provided by the U.S. Army Human Engineering Laboratory (9) (Fig 3). In this figure, the plotted boundary curve represents the ranges of tracking errors which would

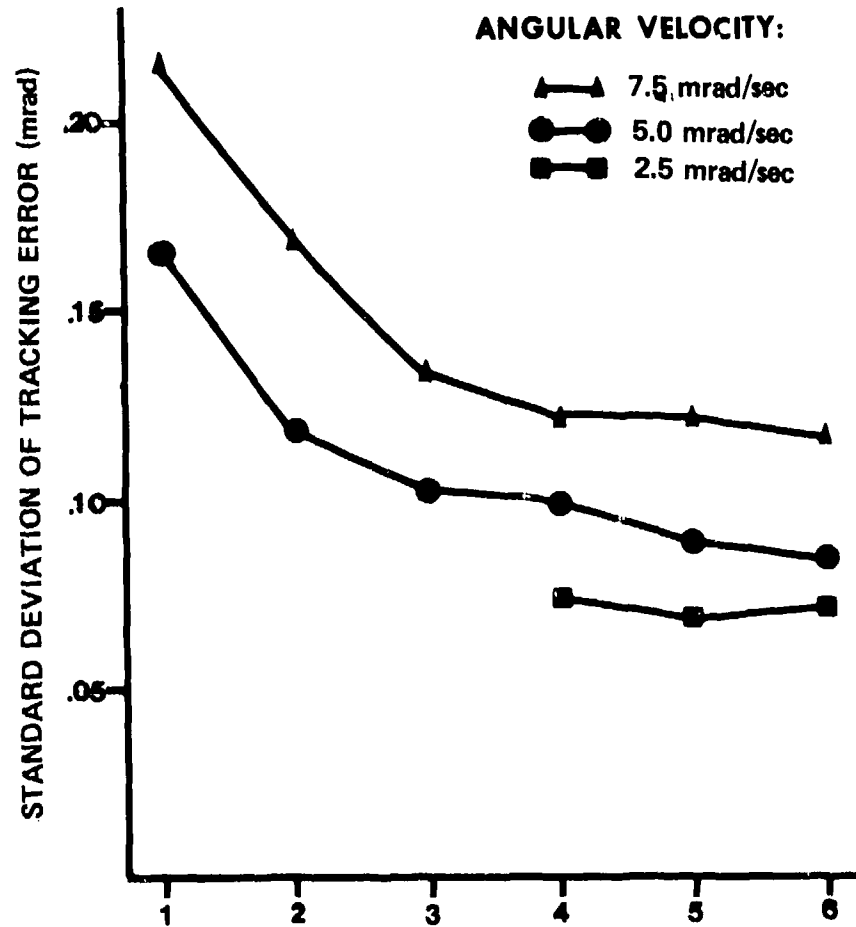


Figure 2. Horizontal error as a function of training and target velocity.

be expected when using the current generation of lightweight, viscous-damped tracking devices under field conditions. The plotted group means ± 2 SEM obtained during this study fall near the lower limits of the predicted range of tracking errors. The relatively precise tracking performance exhibited by participants in the laboratory study might be due to the less demanding environmental conditions (no wind, etc.), the degree of training received by the subjects in this study, and the mechanical characteristics of laboratory designator viscous mount.

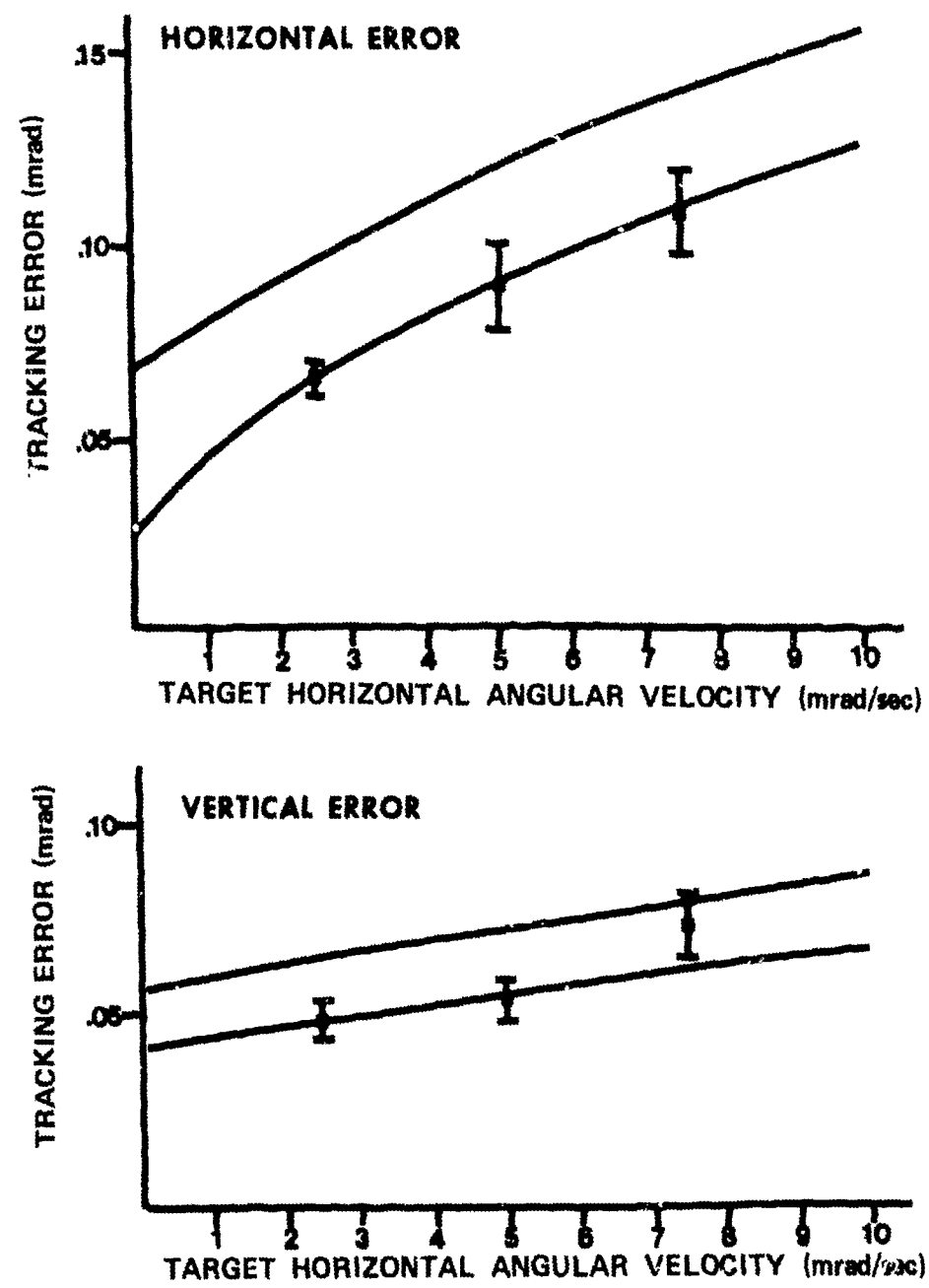


Figure 3. Predicted and observed tracking performance using the laboratory simulator.

The group mean horizontal RMS error scores obtained during sessions 4, 5, and 6 are presented in Figure 4. The results of the ANOVA of these data indicated that the effects of ambient light level, angular velocity sessions, and the interaction of angular velocity with light level were all significant. The post hoc comparisons of the differences between the bright-light and low-light conditions, at all velocities, during each session were significant. When specific comparisons of the velocity conditions were made, all 2.5 to 7.5 mrad/sec comparisons were significant. Additionally, 5 of the six 2.5 to 5.0 mrad/sec and 5.0 to 7.5 mrad/sec comparisons under the low-light condition were significant. However, under the bright-light conditions only 2 of these 6 comparisons were significant. Finally, the significant three-way interaction between sessions, light level, and target velocity can likely be attributed to changes in performance under the low-light conditions when tracking at the 2.5 and 7.5 mrad/sec velocities during these 3 sessions. The difference in horizontal RMS error between the bright-light and low-light condition was approximately 0.05 mrad at the 2.5 mrad/sec velocity, but increased to approximately 0.09 mrad for the 5.0 and 7.5 mrad/sec velocity conditions. The post hoc comparisons of these data, however, indicated that ambient light levels produced significant effects only for the 7.5 mrad/sec target velocity. The significant interaction of light level with angular velocity indicated that not only did error scores increase as velocity increased from 2.5 to 7.5 mrad/sec, but that this effect was even greater for 5.0 and 7.5 mrad/sec velocities under the low-light condition. The added difficulty of tracking under reduced illumination and the partial adaptation noted for the 7.5 mrad/sec velocity across the three experimental sessions emphasize the need to provide laser-designator operators with training under reduced illumination conditions.

PRESENT AND FUTURE RESEARCH

The simulator is now being used to study the effects of stroboscopic flashes on tracking performance. Flashes are presented alone or in combination with evasive target maneuvers while the operator tracks targets under bright or low-light viewing conditions. The results of these experiments indicate that such flashes are extremely disruptive. Future studies of countermeasures will use more complex stimuli (combined flash, noise, vibration, and target obscuration) and will include measures of the physiological response of the operator to these stressful conditions. The tracking performance of operators using various laser protective materials will also be studied in the simulation laboratory.

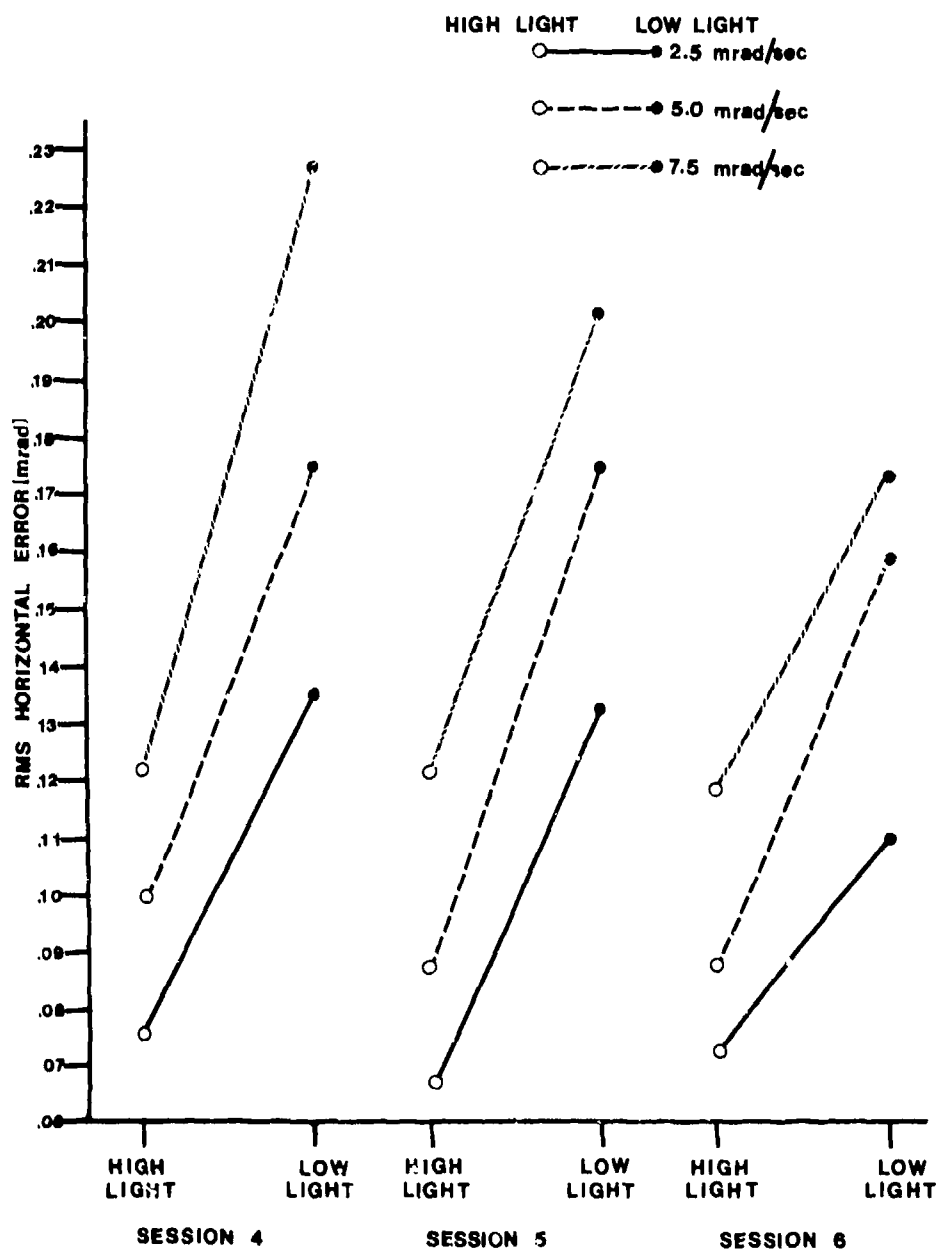



Figure 4. RMS horizontal error scores for high-light and low-light trials at target velocities of 2.5, 5.0, and 7.5 mrad/sec.

CONCLUSIONS

The results of the preliminary studies indicate that the tracking performance data obtained with the use of the laboratory laser designator simulator are consistent with those obtained under field conditions in which prototype viscous-mounted laser designator devices are used. The methods and results outlined in this report demonstrate the feasibility of using relatively inexpensive microcomputer, laser, and video electronic systems to study human tracking performance in a laboratory situation where biomedical variables which influence soldier performance may be monitored under precisely controlled conditions. The data obtained through use of the simulator will be of value during the selection and training of designator operators and will provide information for use in developing means of protecting the operator from the effects of hazardous environments.



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